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Relationships Among CCF Performance, Optempo, and Mission Performance: Final Report

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14. ABSTRACT *(Maximum 200 words)*:

The purpose of this study was to present an exploration of multivariable relationships of unit characteristics, training programs and NTC performance, extending analyses of the "Determinants of Effective Performance of Combat Units at the NTC" data to clarify the relation between unit performance at the NTC and characteristics of the units and their home station training programs.

15. SUBJECT TERMS

OPTEMPO, determinants, National Training Center, unit effectiveness, officer stability

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FINAL REPORT: RELATIONSHIPS AMONG CCF PERFORMANCE, OPTEMPO, AND MISSION PERFORMANCE

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DRAFT FINAL REPORT: RELATIONSHIP AMONG CCF PERFORMANCE, OPTEMPO, AND MISSION PERFORMANCE

Draft Final Report: Relationships Among CCF Performance, Optempo, and Mission Performance

I. INTRODUCTION

A. Background

The ARI project *The Determinants of Effective Performance of Combat Units at the National Training Center* (Keesling, *et al*, 1992a) is the most recent example of attempts to relate home station training to unit performance in combat-like maneuvers. This project confirmed earlier findings (Hiller, McFann and Lehowicz, 1990) that unit OPTEMPO (measured as the mileage accrued by combat vehicles) was a useful predictor of brigade performance during National Training Center (NTC) training exercises. The Determinants project also examined the relationship of other characteristics of home station training to performance at task-force, company and platoon echelon levels. Although there were very few brigades involved in the Determinants project (only seven), the question arose as to whether it was possible to examine the impact of other characteristics of home station training on unit performance at the NTC, controlling for mileage.

The purpose of the present study is to present an exploration of multivariable relationships of unit characteristics, training programs and NTC performance using this small sample of data.

B. Objectives

This report extends analyses of the Determinants data to clarify the relation between unit performance at the NTC and characteristics of the units and their home station training programs. The objectives are:

- To identify the relationship between OPTEMPO and other characteristics of brigades and training programs.
- To identify characteristics of units and training programs that, when combined with OPTEMPO, help to predict NTC performance.

II. METHOD

A. Sample

The sample for this set of analyses was the seven brigades that participated in training rotations (from fiscal years 1989 and 1990) monitored by the Determinants project. The brigades came from three divisions: three from one division, and two each from the other divisions. All divisions were from different installations.

B. Measures

Eight categories of measures will be considered: (a) unit performance at NTC, (b) OPTEMPO, (c) training management, (d) simulators, (e) personnel stability, (f) cohesion, (g) leadership, and (h) personnel characteristics. All measures were aggregated to the brigade level. The measures are discussed in greater detail below. These measures were found to bear interesting relationships to unit performance (at different echelon levels) in the Determinants project. Additional information may be found in Keesling, *et al*, 1992a and 1992b.

1. Unit Effectiveness. The effectiveness measure, the outcome of interest, was based on ratings by NTC OCs (observer controllers). After each mission, battalion task force OCs rated the mission as successful or unsuccessful. The measures for analysis in this report were the number of successful force-on-force (FOF) missions performed by the two task forces in each brigade. This number could have ranged from zero to twelve; for the rotations observed it ranged from zero to five.

2. OPTEMPO. The OPTEMPO measure was based on mileage reports from the Army Oil Analysis Program (AOAP), which is managed by the US Army Materiel Command. AOAP periodically analyzes oil samples of combat vehicles (among others). The AOAP database includes odometer readings for each vehicle at the time of each sample. The readings were aggregated to the brigade level (combining both battalion TFs in the typical rotation). The period for analysis was the six months prior to the rotation. The brigades in this analysis averaged between 174 and 758 miles per combat vehicle during the six months prior to their NTC rotations.

3. Training Management. The training management measures were based on surveys administered to officers about one week before and about one month after the rotation. Three measures were based on ratings by company commanders and company executive officers:

> Realistic OPFOR--(After the rotation) realism of the home station opposing force (OPFOR) compared to NTC OPFOR on a three-point scale: About the same; less realistic and demanding; and much less realistic and demanding.
>
> Last Minute Taskings--(Before the rotation) frequency that late or last minute taskings interfered with training on a five-point scale (almost never to almost always).
>
> Schedule Changes--(Before the rotation) the extent to which schedule changes from higher commands detracted from training (same five-point scale as Last Minute Taskings).

Four measures were based on ratings on the same five-point scale by three echelons of officers (platoon leader, company commander, task force commander and S3) before the rotation (ratings were aggregated to give equal weight to each echelon). The measures were:

Correct Weaknesses--Opportunities to correct weaknesses noted during training (includes time in the field and time between events).

Equipment--Extent that lack of equipment detracted from training.

Training Area--Extent that lack of access to training areas detracted from training. (A parallel question asked about access to ranges--results were virtually identical.)

Support and Details--Extent that post support and details detracted from training.

4. Simulators. The only simulator in general use during the Determinants project was the Unit Conduct of Fire Trainer (UCOFT). The measure for UCOFT was the average reticle aim level for crews who went to NTC. The data were extracted from printouts of crew attainment records generated by the UCOFT systems. These measures were available for tank crews only.

5. Stability. Three stability measures were developed to reflect the percent of officers, NCOs, and service members (respectively) who were in the line companies for at least four months prior to the rotation. The measures were based on surveys administered before and after the rotation.

6. Cohesion. Five measures of cohesion were included: organizational affective (shared values); organizational instrumental (unit looks out for welfare); vertical instrumental (confidence leaders are competent); horizontal affective (friendship among peers); and horizontal instrumental (confidence peers are competent). The measures were based on surveys of squad/crew members (not including NCOs and officers) prior to the rotation.

7. Leadership. The analysis also included five measures related to leadership. Three measures concerned tactical/technical skill: one measure each for the platoon sergeant (rated by the platoon leader), the platoon leader (rated by the company commander), and the company commander (rated by the battalion TF commander and S3). Two measures concerned the TF commander: communication skill and decision making (both rated by the staff). The ratings were conducted in surveys prior to the rotation. These variables were judged to be the most important characteristics of leaders in these positions by superiors and subordinates. (See Keesling, *et al*, 1992a, for more details.)

8. Personnel Characteristics. The measure for personnel characteristics was the mean AFQT score for squad / crew members. The scores were drawn from the Enlisted Master File.

III. RESULTS

A. Relations with OPTEMPO

The first set of analyses looked at the relation of the measures of brigade characteristics and training programs with OPTEMPO. The approach was to correlate mean miles per vehicle with the brigade-level measures. The correlations are summarized in Table 1. The questions for measures marked with the symbol ▾ were phrased such that higher scores represent a greater perception that the item rated was a training detractor.

Three measures under training management relate to OPTEMPO: Realistic OPFOR, lack of equipment, and lack of training areas. Units that reported realistic OPFOR had three unique characteristics: OPFOR was external for all echelons, was thoroughly versed in Soviet doctrine, and modified their vehicles to resemble Soviet equipment. Interviews conducted during the Determinants project identified problems with equipment maintenance, especially a lack of spare parts and track. These interviews also revealed that the expressed lack of training areas was not entirely due to small terrain or scheduling conflicts; officers in these brigades thought lack of training funds limited their opportunities for field training.

Though the correlation of OPTEMPO with each of these measures is not statistically significant (given the small sample), the correlations are strong enough to suggest a relationship between OPTEMPO and other training resources. Units with high levels of OPTEMPO also invested in a dedicated, external OPFOR, and they provided ample spare parts to maintain vehicles. Units with high levels of OPTEMPO seemed to have less problem with availability of training areas.

The measures for cohesion also show significant relations with OPTEMPO. These relationships reinforce the effects of high quality training as expressed in FM 25-100, *Training the Force* (1988): "Effective training builds proficiency, teamwork, confidence, and cohesiveness." Of course, the platoons within each brigade differed in reported cohesion, and the effects of other variables at the company and platoon levels would have to be examined to account for this variation.

The negative correlation of EM stability with OPTEMPO is due to the fact that in this limited sample of brigades there was one composed of two COHORT battalions and two others that had a single COHORT battalion. The COHORT units seemed to place less emphasis on field training.

Table 1: Correlations with OPTEMPO

Category	Measure	Correlation
Training Management	Realistic OPFOR	.46
	Correct Weaknesses	.10
	Last Minute Taskings ▾	.16
	Schedule Changes ▾	.16
	Lack Equipment ▾	-.60
	Lack Training Areas ▾	-.53
	Post Spt and Details ▾	-.36
Simulators	UCOFT	-.17
Stability	EM Stability	-.68
	NCO Stability	-.16
	Officer Stability	-.17
Cohesion	Organization Affective	.79
	Organization Instrumental	.87*
	Vertical Instrumental	.87*
	Horizontal Affective	.84*
	Horizontal Instrumental	.88*
Leadership	PSG Tech/Tac	-.31
	PL Tech/Tac	-.04
	Co Cdr Tech/Tac	.60
	TF Cdr Communication	.09
	TF Cdr Decision Making	.06
Personnel Char.	Mean AFQT	.23
		*Sig = -.01

B. Relations with Effectiveness

The next set of analyses looked at the relations of the measures unit characteristics and training programs to unit effectiveness. Three approaches were followed: a strictly quantitative

method -- correlation analysis, and a more qualitative method -- a surface of ordered profiles were used to examine overall relationships to effectiveness. A regression model, with several variations, was used to identify and quantify 'the best' set of variables for predicting effectiveness.

1. Correlation. The first approach was to correlate the measures. The correlations are summarized in Table 2. The questions for measures marked with the symbol ▾ were phrased to identify training detractors; thus a negative correlation is in the expected direction.

The training management measures relate in the expected directions to effectiveness. The resource-related measures are consistently high, with lack of equipment being especially sensitive. In addition, three detractors (that are independent of OPTEMPO) are identified: last minute taskings, schedule changes, and post support and details.

The strength and direction of the UCOFT measure is surprising. The purpose of UCOFT is to enhance crew proficiency and previous analysis of platoon performance confirmed the benefits of this training (Keesling, *et al*, 1992a). At the brigade level the average reticle aim score reflects the general level of crew stability. The tank commander (TC) and Gunner must serve together for a long period to reach the higher reticle aim levels. There is a .67 correlation between UCOFT and EM stability at the brigade level. This correlation arises because COHORT units, which had very high EM stability, also had consistently high reticle aim scores. The COHORT units also tended to have weaker field training (lower amounts of OPTEMPO, lack of equipment cited as a detractor) and they tended to under-perform other units at NTC. One possible explanation is that commanders over-estimated the benefits of stability at lower levels and de-emphasized field training.

Although EM stability was negatively related to success, officer stability showed a strong positive relationship. Two explanations may account for the correlation. Units may have benefited because their principal trainers were in place during the period when the most intensely focussed training was conducted. Or, units may have benefited because the officers themselves were available for training. Since the explanations are not mutually exclusive, both may have contributed.

Table 2: Correlations with Effectiveness

Category	Measure	Correlation
OPTEMPO	Mean Mileage	.60
Training Management	Realistic OPFOR	.73
	Correct Weaknesses	.26
	Last Minute Taskings ▾	-.52
	Schedule Changes ▾	-.55
	Lack Equipment ▾	-.93*
	Lack Training Areas ▾	-.65
	Post Support and Details ▾	-.78
Simulators	UCOFT	-.61
Personnel Stability	EM Stability	-.45
	NCO Stability	.12
	Officer Stability	.63
Cohesion	Organization Affective	.40
	Organization Instrumental	.34
	Vertical Instrumental	.33
	Horizontal Affective	.76
	Horizontal Instrumental	.49
Leadership	PSG Technical/Tactical	-.17
	PL Technical/Tactical	.10
	Co Cdr Technical/Tactical	.21
	TF Cdr Communication	.19
	TF Cdr Decision Making	-.15
Personnel Char.	Mean AFQT	.24
		*Sig = .01

2. Surface of Ordered Profiles. Another approach to examine the impact of the measures on effectiveness is illustrated in this section using a subset of measures. The technique is described more fully by Hendrix and Brown (1990).

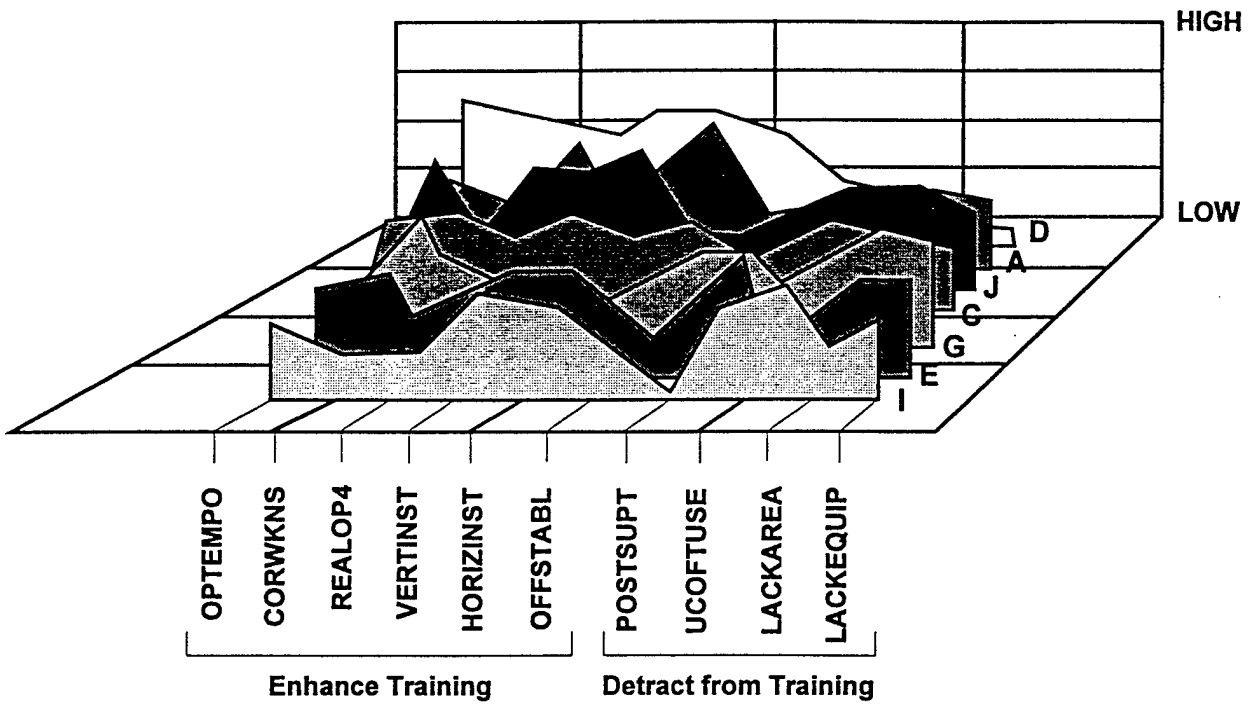

Figure 1: Profile for All Rotations

The profiles on a subset of measures for all rotations is shown in Figure 1. The rotations are in order of success from the front (low success) to the back (high success). The measures have been converted to standard scores. The order of the measures is based on the standard score for the most successful rotation (D -- at the back of the figure).

The profiles are remarkably consistent: successful units are strong across the board, i.e., high on most enhancements and low on most detractors. This pattern is shown more clearly in Figure 2. In that figure, the least and most successful rotations are shown with a moderately successful rotation (C). This display helps identify the variables that distinguish the most successful rotations. Those variables are at the extreme left (high on enhancements) and at the extreme right (low on detractors). In this case the distinguishing variables include three enhancements--OPTEMPO, opportunity to correct weaknesses, and realistic OPFOR--and control of two detractors--lack of equipment and lack of access to training areas.

The surface of ordered profiles allows for a visual, qualitative examination of the relationships of many variables to an outcome. It tends to place variables with similar relationships to the outcome together. A more sophisticated analysis, using software not currently available to project staff, could apply this technique in an exploratory mode: trying different sets of variables and orderings; smoothing within variable clusters; smoothing left to right or back to front, etc.

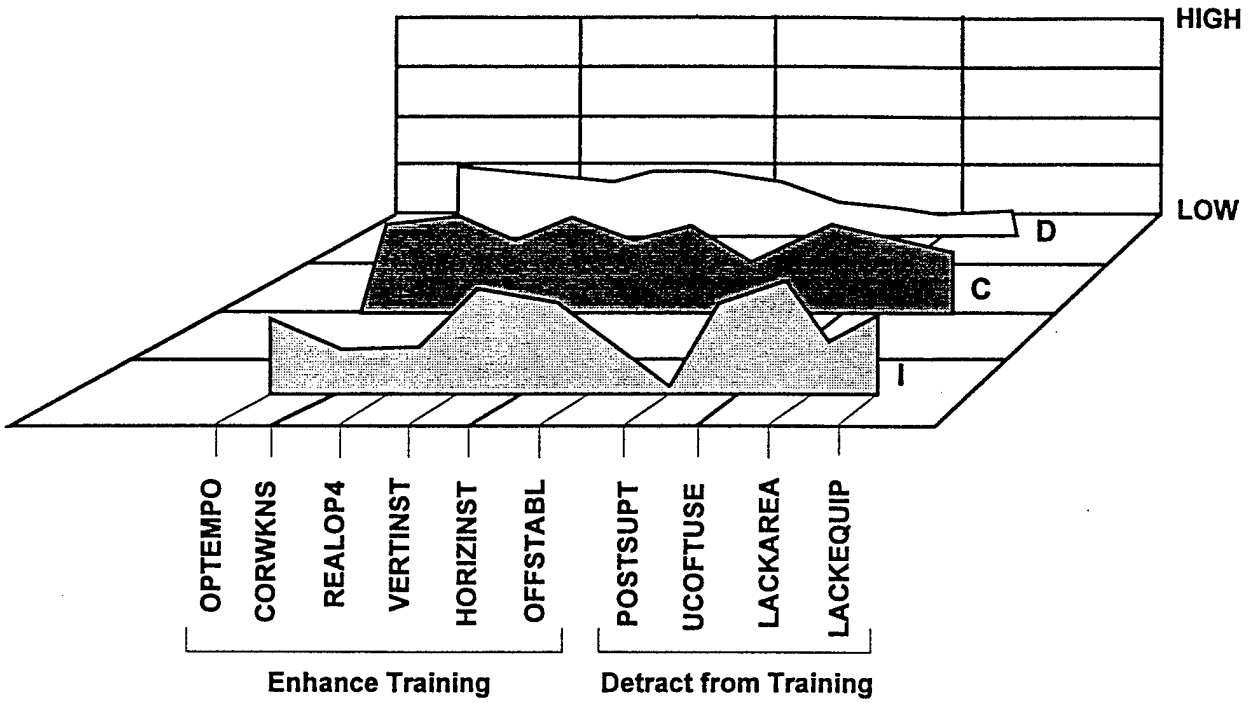

Figure 2: Profiles for Selected Rotations

3. Multiple Regression. The third set of analyses was directed toward identifying variables that, combined with OPTEMPO, would improve the prediction of brigade effectiveness compared to that obtained using OPTEMPO alone. One rationale for these analyses was that such variables might represent a way to compensate for lower levels of OPTEMPO. The approach was to conduct multiple regression analyses starting with OPTEMPO, which has now been demonstrated to relate to brigade effectiveness in two separate samples (Hiller, McFann and Lehowicz, 1990; Keesling, *et al*, 1992a), and searching for variables that improve the prediction of effectiveness.

After OPTEMPO was entered, the next variable that improved the prediction of brigade effectiveness was Officer Stability. No further variables met the criterion for entry into the regression equation[1]. The coefficient of determination (R^2) for this two variable model is .912, meaning that just over 90 percent of the variation in brigade effectiveness is explained by a linear combination of OPTEMPO and Officer Stability. This relationship is statistically significant at the alpha=.01 level.

The pattern of the relation between OPTEMPO, Officer Stability, and brigade effectiveness is shown in Figure 3. In that figure, effectiveness is shown on the vertical plane

[1] No other variable could improve prediction of brigade effectiveness at the chosen level of statistical significance (alpha = .05).

(the scores run from -1 to 6 successful missions so that the point at zero successes can be represented as a 'spike'), Officer Stability (70% to 100%) on the side of the horizontal plane, and OPTEMPO (100 miles to 800 miles) on the front of the horizontal plane. For example, the most successful (tallest) rotation had substantially more OPTEMPO than any other rotation and had as much officer stability as all but one other rotation. The second most successful rotation, had less than average OPTEMPO, but compensated with the highest level of officer stability. The least successful rotation had the lowest level of officer stability and was in bottom half for OPTEMPO.

The fitted regression model is represented by the slanted plane that is superimposed on the data points. It shows that both OPTEMPO miles and Officer Stability are positively related to performance at NTC. The formula for the regression plane is:

Number of successes = -15.07 + .006163*(OPTEMPO miles) + .1642*(Officer Stability)

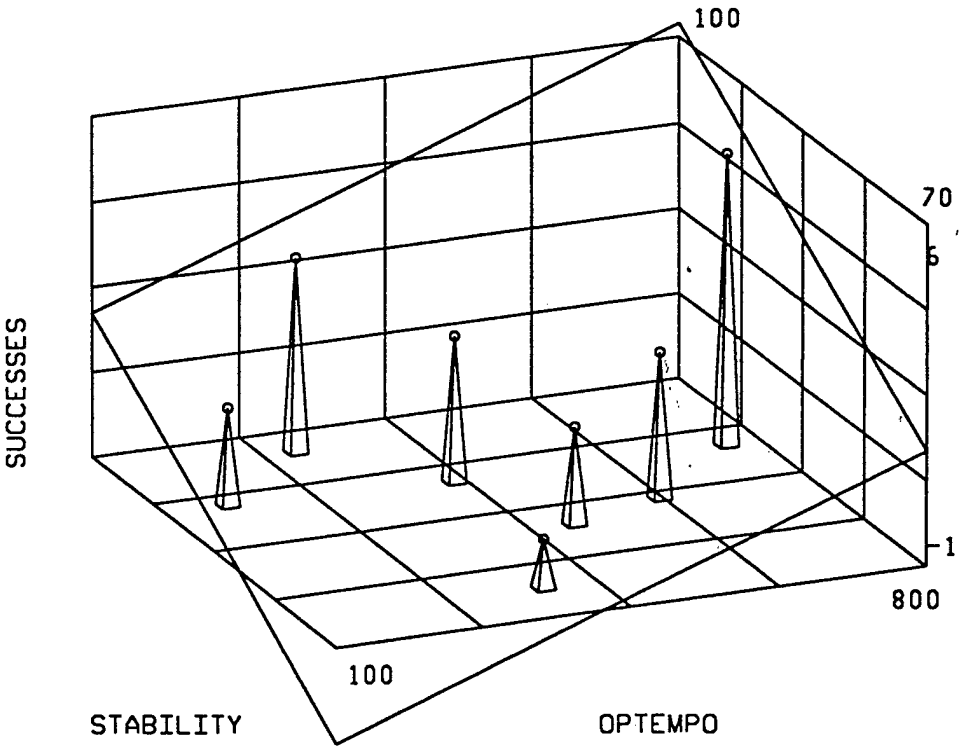

Figure 3: Regression Plane Fitted to OPTEMPO and Officer Stability

Table 3 presents the correlations of Officer Stability with the other variables characterizing the brigades and their training programs. Notable among these are the negative correlations for schedule changes, last minute taskings and post support and details: the more stable the line officers, the less likely these were reported to detract from training. The negative

relationship with UCOFT usage and the positive relationship with realism of OPFOR indicate that stability of line company officers is associated with emphasis on realistic field training.

Some of the difficulties and nuances of interpreting this regression model predicting brigade performance based on OPTEMPO and Officer Stability are explored from a statistical perspective in Appendix A. The implications for the main thread of discussion are that the overall equation seems to fit the data very well and that OPTEMPO and Officer Stability are about equally important in determining the performance of units at NTC.

Table 3: Correlations with Stability of Line Company Officers

Category	Measure	Correlation
OPTEMPO	Mean Mileage	-.17
Training Management	Realistic OPFOR	.54
	Correct Weaknesses	.22
	Last Minute Taskings ▾	-.90*
	Schedule Changes ▾	-.66
	Lack Equipment ▾	-.46
	Lack Training Areas ▾	-.07
	Post Support and Details ▾	-.62
Simulators	UCOFT	-.62
Personnel Stability	EM Stability	.02
	NCO Stability	.30
Cohesion	Organization Affective	-.24
	Organization Instrumental	-.27
	Vertical Instrumental	-.29
	Horizontal Affective	.21
	Horizontal Instrumental	-.07
Leadership	PSG Technical/Tactical	-.15
	PL Technical/Tactical	-.06
	Co Cdr Technical/Tactical	-.32
	TF Cdr Communication	-.05
	TF Cdr Decision Making	-.34
Personnel Char.	Mean AFQT	-.12
		*Sig = .01

As the two variables are equally important in the sense of the prediction equation, then policy implications may be derived from information about the costs of manipulating the variables[2]. If variables A and B are equally important to predicting the outcome, and A is less costly to manipulate, then changing variable A would be the most likely place to start a program of intervention. In the present case, the Army has developed costs associated with OPTEMPO (see FM 25-100 for a brief explanation of the costs of conducting field exercises), while the present authors are not aware of any assessments of the costs of increasing officer stability.

Another way to explore the implications of the regression model depicted by Figure 3 is to use the regression model to estimate the amount of OPTEMPO required in conjunction with different levels of Officer Stability in order to reach specified levels of performance. This analysis is displayed graphically in Figure 4. In this figure three levels of attainment are hypothesized: five, six and seven successes (approximately 40, 50 and 60 percent of the 12 missions that task forces in a brigade conducted at the time of the Determinants project). The line for each level of attainment shows how much OPTEMPO is required to balance the amount of Officer Stability. Thus, even at 100 percent Officer Stability, it would require nearly 600 OPTEMPO miles to attain five successes. If Officer Stability drops to 70 percent, then 1700 OPTEMPO miles are required to attain seven successes.

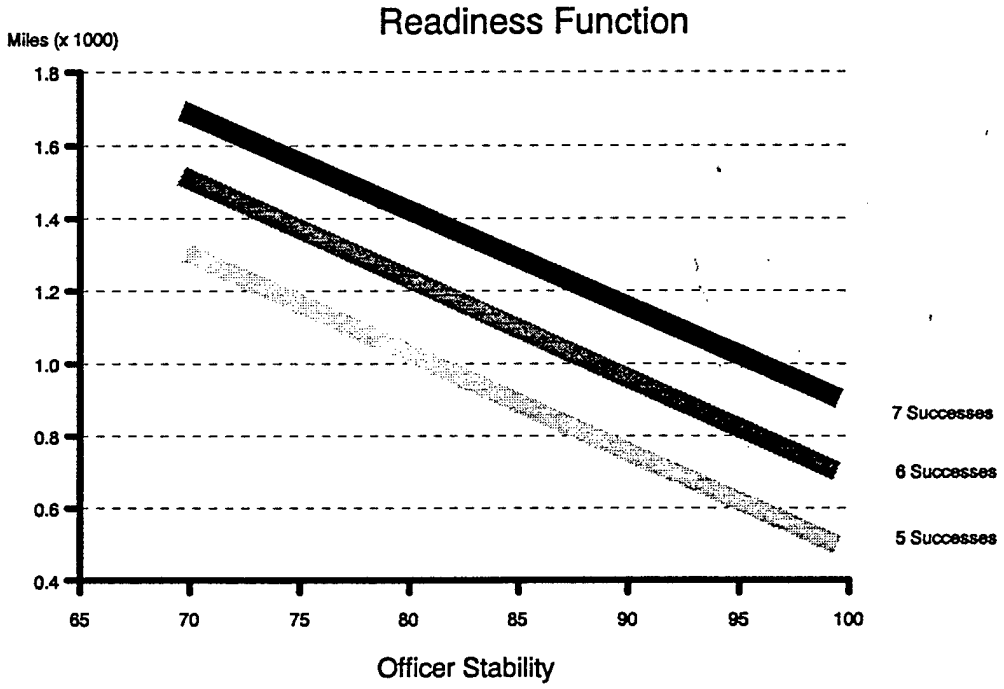

Figure 4: NTC Performance as a Function of OPTEMPO and Officer Stability

[2] If the two variables were not equivalent in the sense of predicting the outcome, then the policy implications would involve both the costs of manipulating the causes and their differential effects on the outcome.

t to recall that the equation used to generate Figure 4 was based on the
ıny officers (not HHC), and that the OPTEMPO miles were calculated over
prior to the NTC rotation. The implication of the last fact is that while
ount of OPTEMPO miles needed to prepare for a rotation, an additional
O miles would be needed to sustain this level of performance after the
, if personnel are changed during this sustainment period, then more
ıld be required to bring the unit back to the previous state of readiness. No
drawn for stretching the OPTEMPO mileage over longer periods of
'orgetting effects' might begin to influence the degree to which units can
ıroficiency.

IV. CONCLUSION

analyses conducted for this report illuminate the pervasive influence of
er Stability in unit training. In this sample the major impact of OPTEMPO
d realism of field training: allowing equipment and access to training areas
orted by a dedicated OPFOR. A by-product of this training program seems
ɔed cohesion. The primary impact of stable officers seems to be on
training detractors.

) declines, increasing officer stability could compensate to some extent. The
) of OPTEMPO to the amount and realism of field training suggests that it
r commanders to maintain as much realism as needed if training budgets
has embarked on a program to develop simulations and simulators to
ıing amount of field training. The effectiveness of these training programs
with respect to performance of brigade-sized units at the NTC.

e training management practices that can maximize training benefits of even
es:

realism of field training at all levels (e.g. trained OPFOR).

ts from training detractors.

ɛrsonnel, especially officers.

VI. APPENDIX A: Further explorations of the regression model

A. Shrinkage in R^2. One of the difficulties with regression analysis is the degree to which one can depend upon the coefficient of determination to characterize the true degree to which the predictor variables account for the dependent variable. Allowing the algorithm to select the variables for inclusion in the equation, makes it likely that 'capitalization on chance' will make the coefficient of determination too high. A standard adjustment to this coefficient indicated that .87 might be a more likely value to expect from repeated studies of this nature.

Another way to examine the variability of the coefficient of determination is to conduct a bootstrap analysis (Efron and Tibshirani, 1991) to generate an empirical measure of variability. The application of this technique requires creating a number of pseudo-samples from the original set of cases. Each pseudo-sample has the same number of cases as the original sample (seven in this case), but because the pseudo-samples are created by sampling with replacement, any one case may appear more than once in a pseudo-sample. The analysis is performed for each pseudo-sample and the observed variability in the statistic of interest (in this case the coefficient of determination) is the result of interest. A program for structural equation modeling that has this bootstrapping capability (Arbuckle, 1993) was used to draw 100 samples for analysis. The standard error estimated from these samples was .032, so a two standard error (approximately 95 percent) confidence interval for the value of R^2 runs from .848 to .976.

B. Importance of Predictor Variables. Another question that arises in regression analysis is the determination of the relative importance of the predictor variables. In the present example we have two predictors: OPTEMPO and Officer Stability. They are nearly equally correlated with NTC performance (.601 for OPTEMPO, and .627 for Officer Stability) and are slightly correlated with each other (-.174). If the relationship between the two was zero, then the two correlations could be compared directly. Ignoring the small correlation between the two predictors, their correlations with the performance measure are nearly equal.

When both are entered into the prediction equation, the standardized regression coefficients are another possible measure of relative importance. In this case, the coefficient for OPTEMPO is .732 while that for Officer Stability is .754; these are also virtually indistinguishable in magnitude. The AMOS methodology was used to fit a model to the data in which the two standardized regression coefficients were restricted to be equal. This model fit the data adequately, indicating that the two coefficients could be considered equivalent.

A method described by Kruskal (1987), which is similar to one proposed by Peaker (1975), averages the percentages of variance accounted for by each variable over all possible orderings of the entry of the variables into the equation. The average percentage of variance accounted for by OPTEMPO is .608, while the average accounted for by Officer Stability is .627: again not of distinct magnitude.